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UPPER AIR OVER THE FALKLAND ISLANDS

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Introduction.—This article is a preliminary survey of the upper air over the Falkland Islands; it is based upon observations by radio-sonde at Port Stanley (51°42′S., 57°51′W., 159 ft. above M.S.L.) taken during the period February 1948 to May 1950. The radio-sonde data from Port Stanley are received month by month in the Meteorological Office where they are punched on Hollerith cards; and Hollerith equipment was used for the initial sorting and tabulations of the survey.

Table I shows the number of observations available at the levels: 900 mb. (about 3,000 ft.), 200 mb. (40,000 ft.) and 60 mb. (60,000 ft.). The data used refer to 1500 G.M.T. Observations at other hours were few, and have been omitted as they were not evenly distributed through the year and would have introduced an undesirable bias in the results. No data were received for August 1948, and so results for August are based on one year's observations only.

TABLE I—NUMBER OF OBSERVATIONS OF TEMPERATURE AND WIND OVER PORT STANLEY

Time of observation: 1500 G.M.T. Period: February 1948–May 1950

	900 mb.		200 mb.		60 mb.	
	Temperature	Wind	Temperature	Wind	Temperature	Wind
	number of observations					
Jan.	31	11	27	0	3	0
Feb.	34	30	28	5	5	0
Mar.	32	43	30	6	7	1
Apr.	38	39	34	6	5	0
May	58	42	52	16	7	1
June	33	27	27	11	3	1
July	28	28	23	11	1	0
Aug.	15	19	14	7	0	0
Sept.	31	22	23	11	0	0
Oct.	22	26	22	6	4	1
Nov.	30	28	27	2	1	0
Dec.	35	16	29	4	2	0
Year	387	331	336	85	38	4

*The original report, of which this article by Miss. N. Carruthers is a summary, was prepared by Mr. R. Gray of Aberdeen University when he was working in the Upper Air Climatological Section of the Meteorological Office in the summer of 1950.

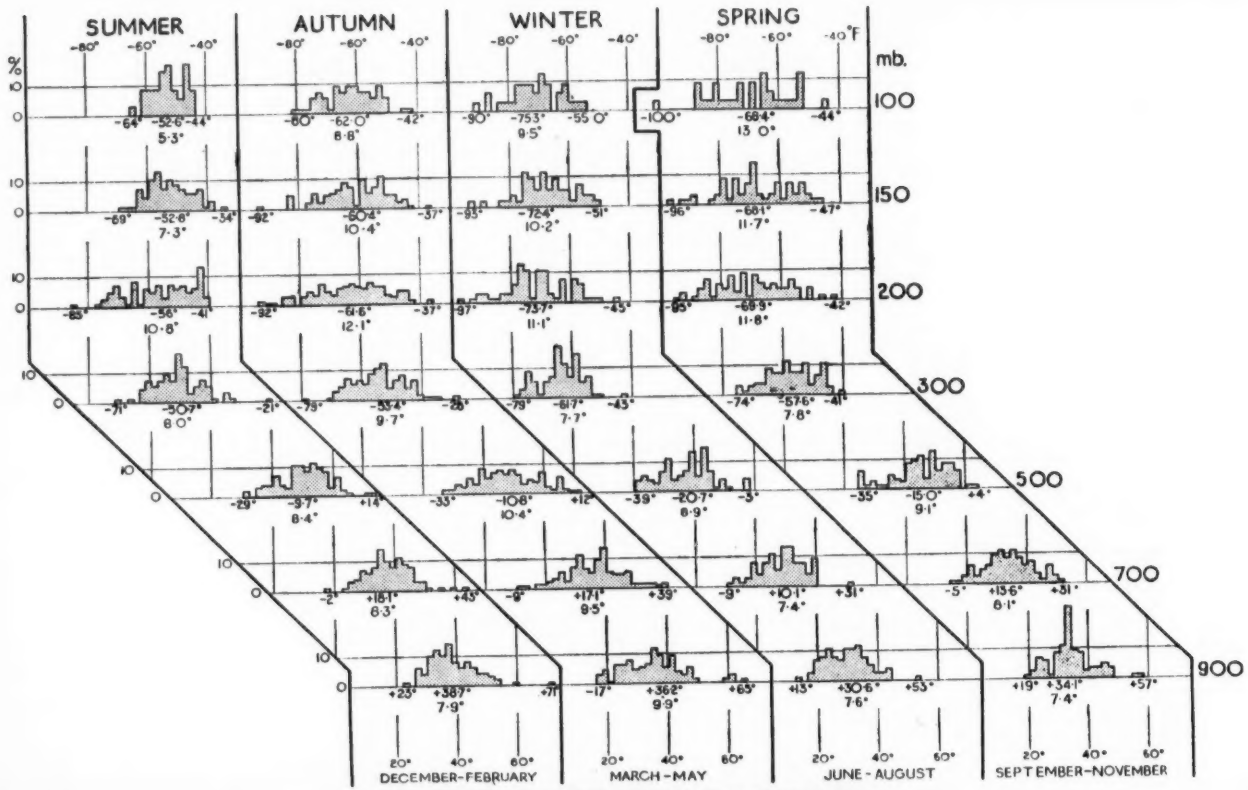

FIG. I—UPPER AIR TEMPERATURES OVER PORT STANLEY

Percentage frequencies of ranges of 2°F. at 1500 G.M.T., February 1948 to May 1950

The values below each histogram are:— { Minimum Average Maximum / Standard deviation } expressed in degrees Fahrenheit

The data are presented under three main headings: temperature, wind, tropopause. No analysis of humidity has been attempted.

Temperature.—Fig. 1 gives the percentage frequencies of temperature in steps of 2°F. for the four seasons, summer (December to February), autumn (March to May), winter (June to August) and spring (September to November), at the isobaric levels: 900, 700, 500, 300, 200, 150 and 100 mb. The histograms for 850 and 800 mb. (not reproduced here) are very similar to those at 700 mb., but with a general shift to the right associated with slightly higher average temperature. The figures given below each histogram show in the centre the average seasonal temperature at the specified level with the standard deviation of the individual observations below it, and on either side the extremes.

These data give an indication of the annual variation of average temperature as well as showing the absolute range in each season. Neither annual variation nor the absolute range in each season shows much change with height up to the 300-mb. level, but in both there are sudden increases at 200 mb. Decreases, in some seasons, above this level may be due to decreases in numbers of observations. The standard deviation varies with height in a similar manner in each season except that a secondary maximum tends to occur at 500 mb. in winter and spring. This has been found also in the northern hemisphere: at Larkhill, Salisbury Plain (51°12′N., 1°48′W.) and at Juneau, Alaska (58°22′N., 134° 35′W.) there is, in January, a maximum at 500 mb. and a very distinct minimum in the neighbourhood of 300 mb., above which the standard deviation increases to another maximum between 200 and 150 mb.

Fig. 2 shows the variation with height of absolute extremes and of average temperature, the latter being plotted for the midwinter and midsummer months.

It is not possible to assess the diurnal variation of upper air temperature from the data available.

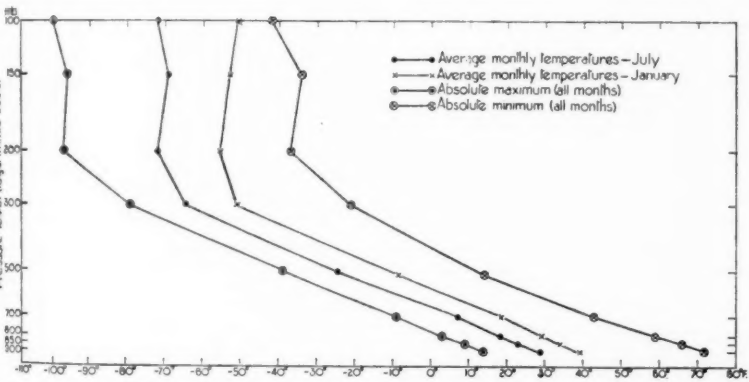

FIG. 2—VARIATION WITH HEIGHT OF UPPER TEMPERATURE OVER PORT STANLEY
Time of observations: 1500 G.M.T., February 1948–May 1950

Wind.—The upper wind data are summarized in Fig. 3. This gives seasonal wind roses at standard levels from 900 to 150 mb. with the corresponding average speed in knots to the right of each wind rose.

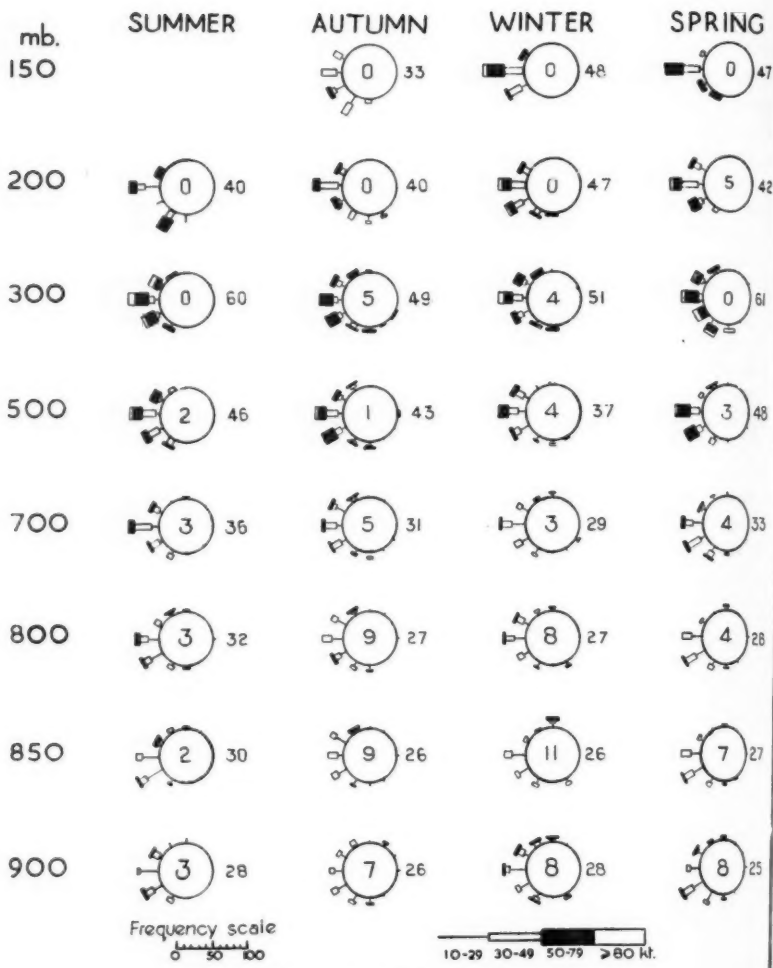

FIG. 3—UPPER WIND ROSES AT PORT STANLEY

The figures within the station circles give the percentage frequencies of wind speeds below 10 kt. Figures to the right of each wind rose give the average speed in knots.

Wind speeds increase with height up to 300 mb. Above this level speeds appear to fall off; but this effect may arise from loss of observations at high levels. The dominant direction in all seasons is westerly, except that in spring SW. winds predominate at levels up to 700 mb.

Tropopause.—Table II gives percentage frequencies of pressure at the tropopause over Port Stanley. These frequencies have been computed for the four seasons irrespective of the temperature and type of the tropopause. The relatively large scatter in autumn probably arises from the larger number of observations, three years' data being available only for this season. Similarly,

paucity of observations may be responsible for the relatively small scatter in winter. The values of average pressure, given at the foot of the table, show that the tropopause tends to be lower in summer and winter than in autumn and spring, but the difference is less than twice its standard error. The standard error of each average was computed from the formula,

$$\text{Standard error} = \sqrt{\left(\frac{\text{Variance}}{N/3}\right)}$$

TABLE II—SEASONAL FREQUENCY OF PRESSURE, AVERAGE PRESSURE AND TEMPERATURE AT THE TROPOPAUSE OVER PORT STANLEY

Range	Summer (Dec.–Feb.)	Autumn (Mar.–May)	Winter (June–Aug.)	Spring (Sept.–Nov.)	Year
mb.		*percentage frequency*			
130–9	...	1	...	...	<0·5
140–9	...	...	...	...	...
150–9	...	...	...	...	...
160–9	...	3	...	...	1
170–9	2	2	3	5	3
180–9	2	4	...	5	3
190–9	3	3	...	6	3
200–9	5	5	10	9	7
210–9	6	4	7	8	6
220–9	7	14	9	8	10
230–9	6	7	12	15	10
240–9	16	8	9	3	9
250–9	4	13	6	4	7
260–9	11	7	3	12	9
270–9	6	3	6	8	5
280–9	3	6	2	6	4
290–9	8	6	7	1	6
300–9	2	2	7	5	4
310–9	5	2	6	3	4
320–9	6	2	...	...	2
330–9	3	2	2	...	2
340–9	1	2	4	1	2
350–9	...	1	3	...	1
360–9	2	1	3	...	1
370–9	...	...	...	...	...
380–9	1	1	1	1	1
390–9	...	...	...	...	...
400–9	...	...	...	...	...
410–9	1	...	...	...	<0·5
420–9	...	1	...	...	<0·5
		millibars			
Average pressure	263	249	261	240	254
Standard error	9·0	7·8	10·5	8·4	4·4
		degrees Fahrenheit			
Average temperature	−64	−68	−76	−73	−70
Number of observations	88	121	68	76	353

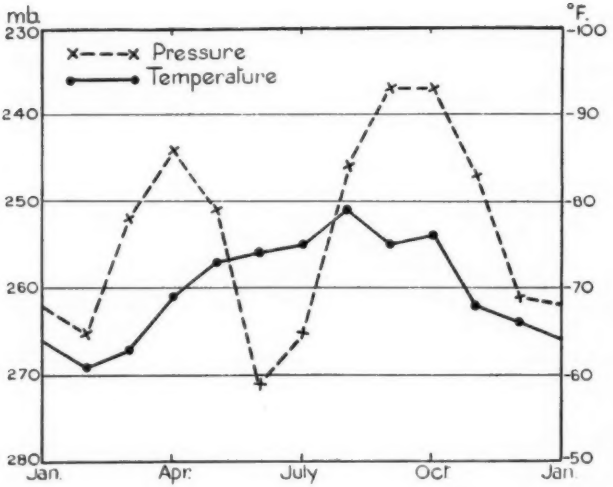

FIG. 4—AVERAGE MONTHLY PRESSURE AND TEMPERATURE AT THE TROPOPAUSE OVER PORT STANLEY

where N is the number of days for which observations are available. The factor 3 is introduced to allow for " persistence " from one day to the next.

Average temperatures also, for the four seasons, are given in Table II; and the average monthly values of pressure and temperature at the tropopause are plotted in Fig. 4. It will be seen that winter average temperatures were low in spite of the low level of the tropopause in June and July. An examination of mean values of tropopause pressure in individual years suggests that the semi-annual oscillation, shown in Fig. 4, may be peculiar to the particular two-and-a-half years under survey.

A high positive correlation was seen to exist between pressure and temperature at the tropopause, comparable with that found by C. H. B. Priestley[1]. Priestley gives correlation coefficients of +0·75, between temperature and pressure at the tropopause, and −0·47 between temperature and height. The latter shows rather less correlation than the value of −0·68 given by W. H. Dines[2].

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1. PRIESTLEY, C. H. B.; Characteristics of the tropopause over southern England, 1944. *S.D.T.M. Met. Office, London*, No. 107, 1945.

2. DINES, W. H.; The characteristics of the free atmosphere. *Geophys. Mem., London*, **2**, No.13, 1919.

UNUSUAL DEEPENING OF A FRONTAL DEPRESSION OVER THE BRITISH ISLES

By E. J. SUMNER, B.A.

The purpose of this article is to give a factual account together with a theoretical discussion of a depression which deepened over the British Isles on October 24-25, 1945. But, before doing so, it is necessary to present as briefly as possible the theoretical ideas on which the study is based.

Theoretical background.—The following treatment is based on a theory of development in relation to the thermal field by Sutcliffe[1]. In this theory Sutcliffe assumed that some of the essential features of the formation of pressure systems could be explained in terms of a relatively simple convergence-divergence model. The " development ", as measured by the relative divergence (i.e. the vertical motion) between two given pressure levels p and p_0 ($p_0 > p$), is given by the equation:—

$$l\,(\mathrm{div}_p \mathbf{V} - \mathrm{div}_p \mathbf{V}_0) = -\,V' \frac{\partial}{\partial s}\,(l + 2\zeta_0 + \zeta') \qquad \ldots\,(1)$$

in which $\mathbf{V}$ is the horizontal wind vector, $\mathrm{div}_p \mathbf{V}$ the isobaric divergence, ζ the vorticity at the pressure level p (suffix o refers to the lower level p_0), V' is the magnitude of the wind shear (the thermal wind) between p and p_0, $\partial/\partial s$ denotes differentiation in the direction of shear, ζ' is the thermal vorticity and l is the Coriolis parameter.

The relative divergence must be positive for cyclonic development (ascent), and negative for anticyclonic development (subsidence). The expression on the right of equation (1) may be considered as three separate terms, the first of which is small as is the second in the early stages of the formation; in any case the second is mainly concerned with the steering of the disturbance. The third term, $-\,V'\partial\zeta'/\partial s$, the so-called thermal vorticity effect, is the primary development factor.

The reader is referred to the original paper[1] for a full discussion of the simplifying assumptions on which this equation depends, but one consideration is relevant here, namely, that the flow was treated as quasi-horizontal throughout. In particular, only the modifications of the thermal pattern due to horizontal advection were considered, and the simultaneous changes due to the vertical motion which necessarily accompanies the development were explicitly omitted. Although vertical velocities in the atmosphere are small compared with horizontal wind speeds, they exercise a disproportionate effect (depending on the departure of the vertical temperature lapse from neutral stability) on the thermal field by virtue of adiabatic temperature changes, which react directly or indirectly on the entire field of development.

The above equation may be extended to include this effect by the addition of a further term[2], and becomes:—

$$l\,(\mathrm{div}_p \mathbf{V} - \mathrm{div}_p \mathbf{V}_0) = -\,V' \frac{\partial}{\partial s}\,(l + 2\zeta_0 + \zeta') + \alpha \nabla_p{}^2\,(\overline{\Gamma w'}) \qquad \ldots\,(2)$$

In this last expression α is a positive constant for the particular layer of the atmosphere under consideration, Γ is the departure of the actual temperature lapse rate γ from the wet or dry adiabatic γ_a, whichever applies, and is negative for instability and positive for stability, while w' is the vertical velocity relative to (moving) isobaric surfaces. The bar placed over the product $\Gamma w'$ implies an average taken vertically throughout the layer with respect to a logarithmic pressure scale; $\nabla_p{}^2$ is the Laplacian operator, $\partial^2/\partial x^2 + \partial^2/\partial y^2$, and l is the Coriolis parameter.

The function $(\alpha/l)\,\nabla_p{}^2\,(\overline{\Gamma w'})$ represents the isallobaric divergence associated with the dynamical temperature changes in an air column. Its contribution to the relative divergence depends on the stability of the atmosphere and the field of vertical motion in the sense that stability opposes both cyclonic and anticyclonic development and instability promotes it. The effect may therefore be

called the " field-stability " effect; in practice horizontal variations in the stability parameter may also be of great importance especially in the case of cyclogenesis when frontal discontinuities and sudden transitions from clear to cloud-laden air are likely to occur. However, we here limit ourselves to a consideration of fairly uniform conditions in order to give an indication of the physical nature and the relative magnitude of the effect in question.

A more quantitative assessment may be made on the assumption that the field of $\overline{w'}$ is symmetrical, and has a maximum near to the centre of the pressure system falling sinusoidally to zero on a circle radius R, which we may identify with the size of the system, i.e. $w' = A \cos(\pi x/2R) \cos(\pi y/2R)$, x and y being rectangular co-ordinates; A is positive for ascending motion and negative for subsidence. Ignoring variations in Γ, the field-stability term has an absolute maximum at the centre ($x=0$, $y=0$) of $(\pi^2 \varkappa A\Gamma)/(2lR^2)$. For vertical ascent the sign of this expression is positive for instability (Γ negative) and negative for stability, the signs being reversed for subsidence. Thus atmospheric stability damps and instability promotes both cyclonic and anticyclonic development. The magnitude of the effect is inversely proportional to the area of the system, other things being equal, and it may be shown[2] that for systems of radius 400 Km. or more it makes a negligible contribution to the relative divergence; but for smaller systems and for average values of the stability parameter the effect can be of dominating importance.

Subsidence is almost invariably associated with atmospheric stability (super dry-adiabatic lapse rates in deep layers are virtually unknown in the free atmosphere) and the formation of small dynamic anticyclones is more or less impossible owing to strong stability damping. The only possibility of instability in depth arises when the air is saturated and the criterion of neutral stability is the saturated-adiabatic lapse rate. Such conditions are, however, seldom found — turbulent mixing would soon destroy them if they were; the rare circumstances in which they could occur are most likely to be effected by the lifting of a convectively unstable air mass in association with a particular cyclogenesis. In most extratropical cyclones the warm air involved in the ascent is stable, except in shallow layers, and the field-stability effect acts as a damping factor which opposes the primary term. As neutral stability is approached the brake is progressively released, and for actual instability the effect becomes a positive developmental factor. In such circumstances the development is likely to be extremely rapid and the vertical ascent to reach extreme values.

But, even so, there are several reasons why the ascent should not be too excessive or too prolonged. In the first place, the amount of precipitation would be increased and the work necessary to combat the downward drag of the descending raindrops would be derived, at least in part, from the extra latent energy released. In effect, the threshold of instability is not reached until a lapse rate rather in excess of the saturated-adiabatic is attained[3]. Secondly, the effect of the vertical motion itself is to stabilize the atmosphere in the layer for which the vertical velocity is increasing with height (i.e. up to the level of non-divergence), and to increase the instability above in regions where it is decreasing. One would therefore expect the greatest vertical velocities to extend rapidly upwards until the stratosphere is reached, with increasing stabilization below, the whole process being accomplished in the space of a few

hours. In practice the occlusion process brings in a different and probably more stable air mass below the frontal surfaces, and, when the deepening is marked by decreasing the depth of the " active " warm air between the surfaces and the tropopause (which may also be descending), quickly limits the scope of the eviction mechanism.

The possible effect of instability has been discussed at rather greater length because there is some suggestion, as we shall see, that such was the case in the depression studied. It should perhaps be pointed out that equation (2) is of doubtful validity and must be used with caution when vertical velocity components are particularly large, since it is based on frictionless, quasi-geostrophic, quasi-horizontal motion (except for the effect of the vertical motion on the thermal field), although both terms must make some contribution.

Description.—Figs. 1–4 illustrate the events of the period as they appeared on synoptic charts. The surface isobars and the frontal analyses were accepted as given in the *Daily Weather Reports*, and the 1000–500-mb. thickness lines were obtained by back-gridding from the 500-mb. contour charts (i.e. subtracting the 1000-mb. contours) drawn in the Forecasting Division, Dunstable. No alterations were made to the patterns at all, and, in fact, the lines obtained fitted the observed 1000–500-mb. thickness values almost exactly, with few exceptions. There is, however, some doubt about the drawing of the isobars over the Atlantic in the early stages (Fig. 1) owing to the scarcity of observations.

The depression originally formed at the tip of a warm sector, which had previously broken away from a deep low over Hudson Bay on October 21, 1945, and which went through its life-cycle fairly quickly as a simple wave depression with a wide warm sector, but earlier, while within the American observational network, a secondary cold front had been present. The wave continued to move steadily across the Atlantic round an almost stationary low south-west of Iceland, deepening slowly and occluding, and was approaching Ireland at 1800 G.M.T. on the 23rd. A secondary cold front was re-introduced on this chart (Fig. 1), which, together with the occlusion ahead of it, constituted a pseudo warm sector. Owing to the paucity of observations there was some doubt both as to the position and depth of the centre (it was drawn with a central pressure of about 985 mb.) and, on the midnight chart (Fig. 2), the centre came over Ireland rather further south than would have been expected from the 1800 chart. Its central pressure was then 981 mb. and it seemed to have formed on the secondary cold front and to have detached itself from the occlusion. By 0300 on the 24th the main centre (979 mb.) was moving slowly over southern Ireland but a new centre was forming further north (the pressure tendency at Aldergrove was $-7{\cdot}4$ mb./3 hr.) and by 0600 the centre had been quickly transferred to north-east Ireland (Fig. 3). The central pressure fell to 971 mb., an 8-mb. fall in three hours, which represents an unusually rapid rate of deepening for middle latitudes (the tendency at Aldergrove was now $-9{\cdot}8$ mb./3 hr.).

The depression became very slow-moving after 0600, drifting north-east to Leuchars by 1800, the central pressure then being 968 mb. (Fig. 4). A further low which deepened in our Atlantic approaches later on the 24th and early on the 25th moved rapidly in, and by 1800 on the 25th had amalgamated with its predecessor. The lowest pressure (964 mb.) was recorded at this time when the centre was slowly moving east over north Scotland.

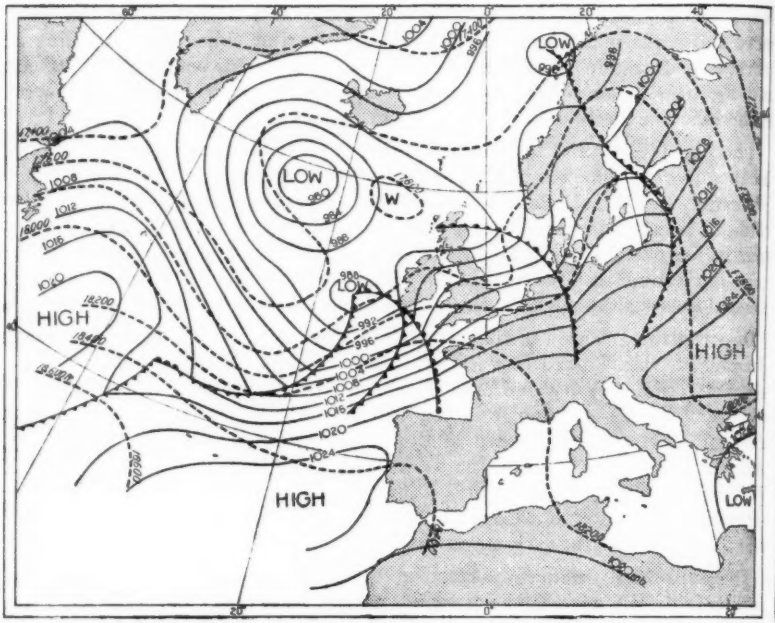

FIG. 1—SYNOPTIC CHART, 1800 G.M.T., OCTOBER 23, 1945

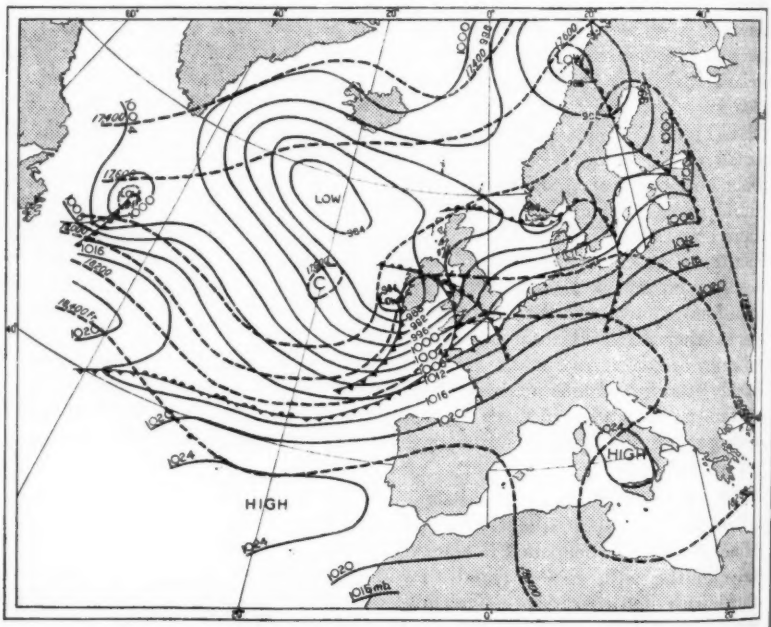

FIG. 2—SYNOPTIC CHART, 0000 G.M.T., OCTOBER 24, 1945

In these charts the full lines are sea-level isobars and the

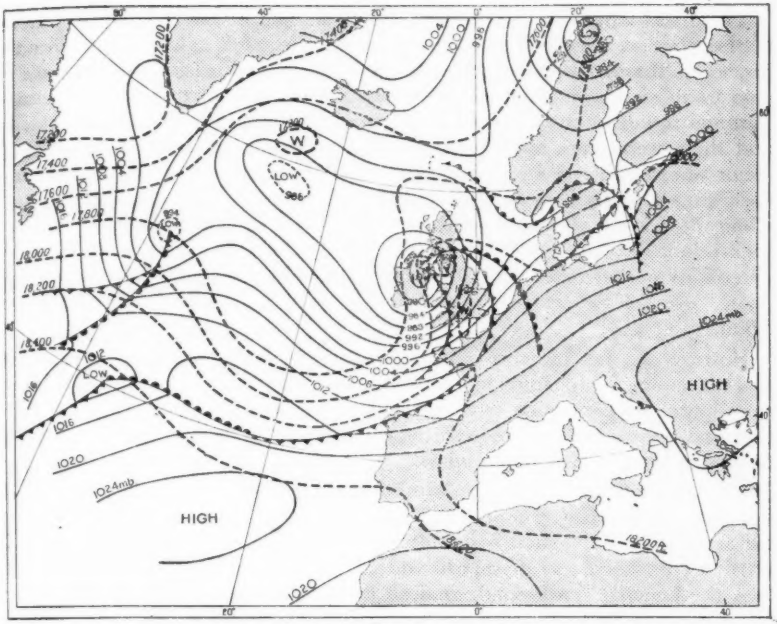

FIG. 3—SYNOPTIC CHART, 0600 G.M.T., OCTOBER 24, 1945

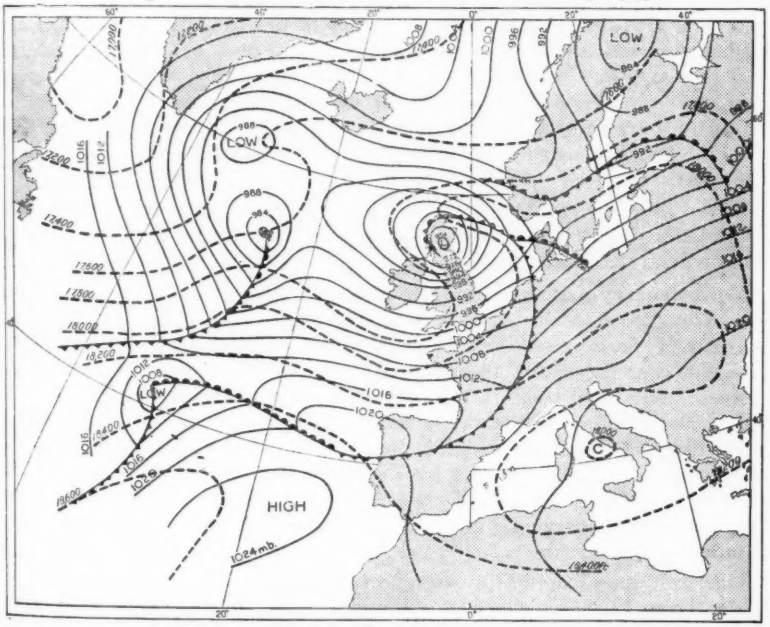

FIG. 4—SYNOPTIC CHART, 1800 G.M.T., OCTOBER 24, 1945

broken lines are 1000–500-mb. thickness lines.

There was moderate to heavy rain along the occlusion and in the narrow warm sector as it crossed southern England; although lightning was seen at Foynes no thunder was reported anywhere in the British Isles. The secondary cold front which swept round the developing centre, gave continuous heavy rain and squalls in a narrow band along its length as it passed over England, and there were large areas of moderate to heavy rain in the pseudo warm sector ahead of it. Very severe gales developed, especially near the centre itself, and here the heavy rain tended to be general rather than concentrated along the fronts. The more continuous and heavy rain was, however, mainly slightly ahead of the centre from about 0300 onwards, with rather showery precipitation elsewhere. Also after 0900, there was something in the nature of an " eye " at the centre of the cyclone, with no rain and some breaks in the cloud.

However, by far the most impressive aspect of this series of synoptic charts was the sequence of changes in the 1000–500-mb. thickness patterns. Although these patterns were similar to what one would expect over a deepening depression, the degree of distortion and the rapidity of the changes, especially early on the 24th, were most spectacular.

The occasion was marked by saturated or very moist warm-sector air and near-neutral stability in depth, probably to the stratosphere. Very few upper air ascents showed actual instability, although the warming in the pseudo warm sector seemed to be due to vertical ascent in an unstable atmosphere. Also the Leuchars radio-sonde showed the warm air above the front (see for example the 0500 and 1100 G.M.T. ascents on the 24th, Fig. 5) to be saturated and slightly unstable in the upper layers. Both the ascents for 0000 at Valentia and 0800 at Aldergrove (on the 29th), each of them practically at the centre of the depression at the times in question, showed practically neutral stability and relatively dry air (Fig. 6). However, at this stage, by far the heaviest rain, and some of the biggest pressure tendencies were well away from the centre in the warm sector over England. Even after the passage of the cold front the Leuchars ascent continued to show almost saturated air in depth with neutral stability (see 0500 ascent on the 25th, Fig. 5).

Sferics were reported at an early stage near the depression centre as it crossed the Atlantic, but during the period of maximum deepening, early on the 24th, there was no sferic activity except in the open warm sector over France.

Commentary.—It is interesting to discuss these events in the light of equation (2). The 1800 thickness chart on the 23rd (Fig. 1) showed a cold trough in the rear of the depression and a weak warm ridge ahead, but the vorticity gradients over the centre, although of the right sign to suggest cyclonic development, were very small. The subsequent evolution was, in the writer's experience, entirely out of proportion to the primary effect, and it seems likely that the absence of stability damping was an important factor in this development. Moreover, as we have seen, there was evidence that the field-stability effect was acting positively at least at some stage of the development. The appearance of warm pools in the pseudo warm sector during the period of most rapid deepening is hard to explain on any other hypothesis.

However, apart from its intrinsic effect, the stability factor produces changes in the thermal field which react on the thermal-vorticity term. The distortion of the associated thickness pattern due to its own circulation seems to be an

essential principle of the organization and self-generation of any depression[1], and the absence of stability (or the presence of instability) would enable the advection to have its full effect, which is not usually the case. The rapid distortion of the pattern in this instance is undoubtedly due to this cause, and, although the thermal-vorticity effect was small initially, it came increasingly into its own as the development proceeded.

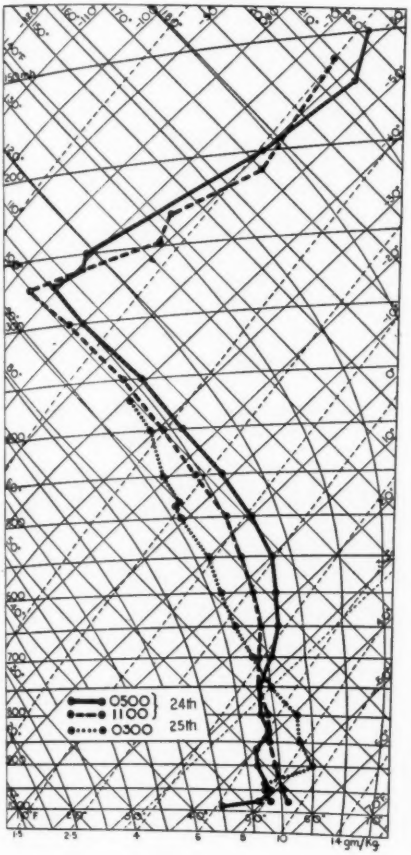

FIG. 5—TEPHIGRAM OF ASCENTS AT LEUCHARS, OCTOBER 24 AND 25, 1945

Erratum.—Ascent on the 25th was also at 0500 G.M.T.

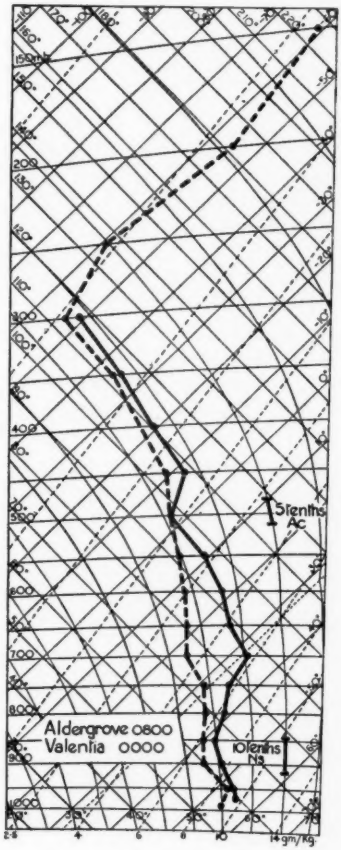

FIG. 6—TEPHIGRAM OF ASCENTS ON OCTOBER 24, 1945

Aldergrove, full line.
Valentia, broken line.

A rough computation of the relative divergence due to the thermal-vorticity term, for the 1000–500-mb. layer and at the centre of the depression at 0000 and 0600 on the 24th, gave values of about 2×10^{-5} sec.$^{-1}$ and 3×10^{-5} sec.$^{-1}$ respectively. These would account for mean vertical velocities of the order of 7–10cm./sec. throughout the layer, which are certainly not excessive. These

computations are easily made on thickness maps, but the field-stability term is much more difficult to evaluate since the actual vertical velocities and the degree of instability at the right time and place are unknown. However, a crude assessment may be obtained from the degree of warming in the pseudo warm sector early on the 24th. For the warm pool in the north Irish Sea, at least, the thickness tendency which may be attributed to dynamical heating is about 100 ft./6 hr.; if Γ is expressed as a multiple of the dry-adiabatic lapse rate, $\beta\gamma_a$ say, then it may be shown that the value of the product of $\beta\overline{w'}$ necessary to produce this degree of warming is about 2/3 cm./sec. Thus if S is $1/15$ which is the approximate value measured from Leuchars ascent in the upper layers, $\overline{w'} = 10$ cm./sec. which is still quite moderate, and smaller degrees of instability and much larger vertical velocities may well have existed. The general rainfall was mainly confined within a radius of 400 Km. from the centre, and, in order to obtain a conservative estimate, this value was used for R in the expression given earlier. These tentative values give 6×10^{-5} sec.$^{-1}$ for the relative divergence due to the field-stability term. It is evident that actual instability was not present over the entire field, but variations in Γ itself from a maximum negative value (instability) in the region of greatest ascent to zero or positive away from it, would enhance the above value. We may therefore conclude that the field-stability effect during the crucial deepening stage was at least as great as the thermal-vorticity effect, and may have been largely responsible for " triggering off " the marked development.

The tendency for the centre to move erratically during the rapid deepening over Ireland is presumably to be expected in all depressions where instability is present, partly owing to the inhomogeneity of the air masses involved and the rapid distortion of the thermal field which may at times throw the maximum development away from the existing centre. The heavy rain saturated the polar maritime air mass in the vicinity of the centre, and the absence of stability damping may have been important in preserving the intensity of the vortex for several days after. In other cases it has been suspected that genuine re-development in the cold air of a fully occluded depression may have originated in this way, the residual vertical motion in the nearly saturated air having produced a certain amount of latent instability.

Conclusion.—The foregoing analysis does not presume to describe the dynamics of the formation of pressure systems in detail, but it is considered that there is a real sense in which their overall development conforms to the general model adopted. This article is mainly concerned with the importance of atmospheric stability in synoptic developments and shows, in a particular case, something of its inherent effect and its possible relation to the other factors involved.

The field-stability effect depends for its operation on the differential heating and cooling associated with organized fields of vertical motion and is automatically called into play whenever they occur. The formulation takes into account the actual field distribution of the stability and the vertical-motion parameters as they happen to be at a particular instant of time; it represents a real physical process and does not depend on the characteristics of a particular model. It almost invariably acts as a damping factor in nature, but on the rare occasions when near neutral stability or actual instability exists or is likely to be realized by a small amount of lifting, particularly rapid and intense developments are to be expected.

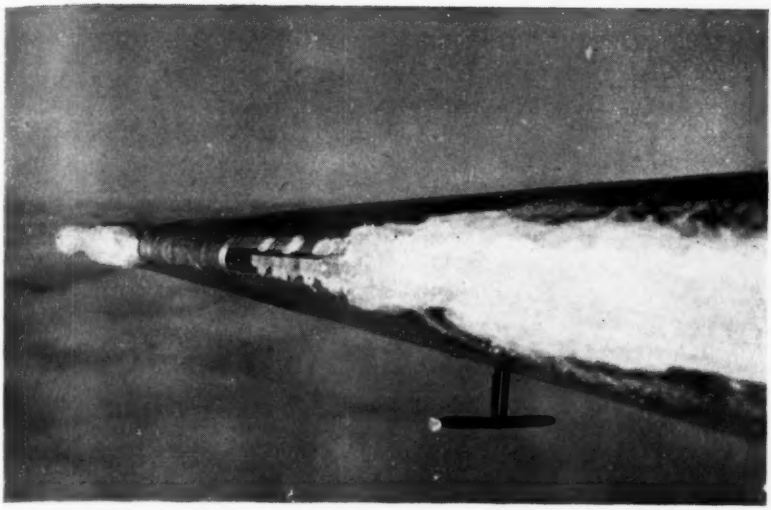

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FIG. 1—ICE ACCRETION ON TAILPLANE, FEBRUARY 27, 1950
The initial ice accretion appeared to be pure rime but later developed into glaze ice
(see p. 140)

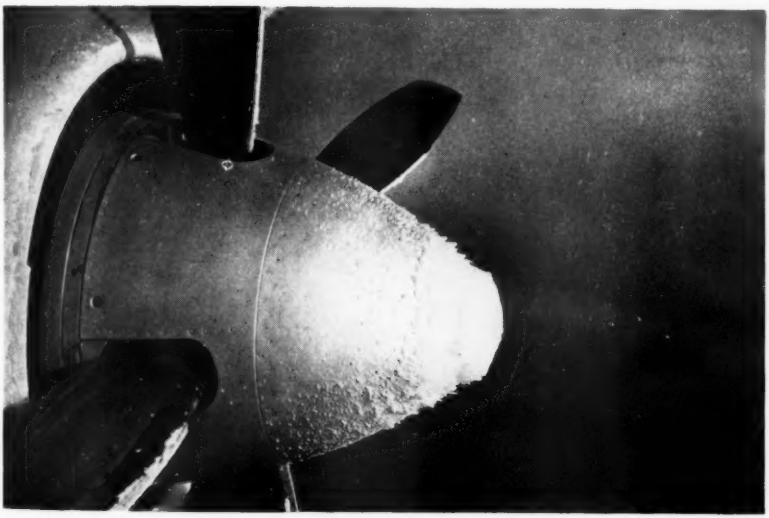

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FIG. 2—ICE ACCRETION ON THE BOSS AND FEATHERED PROPELLOR BLADES OF AN ENGINE AT REST

Reproduced by courtesy of British European Airways

FIG. 3—ICE ACCRETION ON THE ENGINE INTAKE

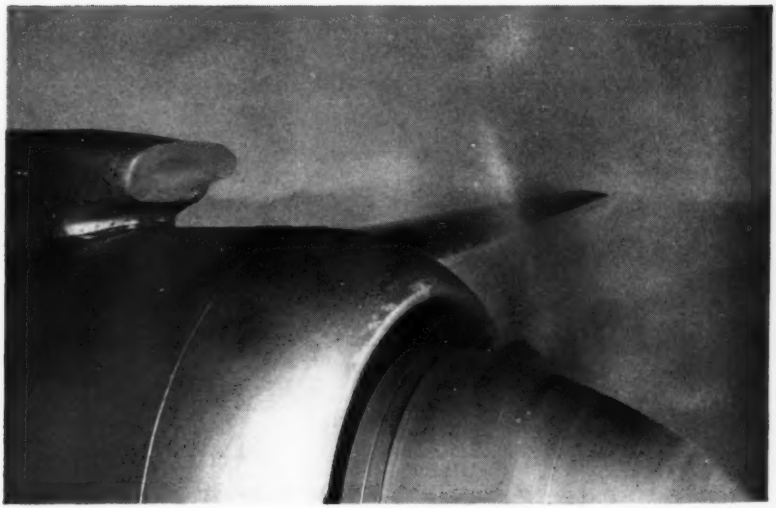

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FIG. 4—ICE ACCRETION ON THE ENGINE INTAKE

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FIG. 5—GLAZE ICING AT THE MAIN PLANE ROOT
The icing was extremely rough and flowery growing into knife-like projections several inches either side of the stagnation point

Reproduced by courtesy of J. Paton

FIG. 1—SIMULTANEOUS OCCURRENCE OF LUMINIOUS NIGHT CLOUDS, NEAR HORIZON, AND AN AURORAL ARC WITH SUNLIT RAYS
Photograph taken at Abernethy, Perthshire (56 20′01″N., 3 18′38″W.) at 0006 G.M.T., July 25, 1950.

Reproduced by courtesy of J. Paton

FIG. 2—LUMINOUS NIGHT CLOUDS SHOWING CHARACTERISTIC WAVE STRUCTURE
Photograph taken at Abernethy, Perthshire, 0148 G.M.T., July 25, 1950

Reproduced by courtesy of J. Paton

FIG. 3—LATER DEVELOPMENT OF LUMINOUS NIGHT CLOUDS, WHICH HAVE NOW EXTINGUISHED THE AURORA
Photograph taken at Abernethy, Perthshire, 0206 G.M.T., July 25, 1950.
Note the characteristic wave structure of the clouds which now extend to an elevation of 24° above the horizon.

The magnitude of the effect is largely dependent on the size of the pressure system, and for large-scale features such as the primary cells of the general circulation or long atmospheric waves it is probably of little direct importance.

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2. SUMNER, E. J.; The significance of vertical stability in synoptic development. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 384.

3. CRADDOCK, J. M.; The effect of water droplets on the bouyancy of a rising cumulus cloud. *Met. Mag., London*, **78**, 1949, p. 351.

INTERNATIONAL METEOROLOGICAL ORGANIZATION

Northern-hemisphere Polar-Year charts

From August 1932 to August 1933 an International Polar Year was organized during which a concerted effort was made to obtain meteorological and other scientific observations for as large a portion as possible of the northern hemisphere, paying particular attention to the Arctic regions. It will be recalled that Dr. Stagg was in charge of the meteorological station established at Fort Rae in northern Canada.

Arrangements were made by which the Deutsche Seewarte at Hamburg undertook to draw the northern-hemisphere meteorological charts for each day of the Polar Year, and to have them printed for distribution to national meteorological services who financed their printing. At the outbreak of war in 1939, portfolios containing charts covering the period August 1932 to April 1933 had been completed and distributed. When peace returned in 1945, arrangements were made to transfer the remaining material to London. This material included charts for May–June 1933 and tracings for July and August 1–16, 1933.

The May–June charts and the July–August charts have recently been distributed to the subscribers to this project. The Meteorological Office has a number of sets of the charts, which have been distributed as follows: two sets to the Meteorological Office Library, and one set each to the special investigations Branch, the Long-Range Forecasting Research Branch, the meteorological office, Edinburgh, Kew Observatory, and the meteorological offices at Malta and H.Q., Middle East Air Force.

The base maps cover the whole of the northern hemisphere on an equidistant azimuthal projection on the plane through the parallel of 60°N. where the scale is 1:30,000,000. The length of the meridian from pole to equator is about 13 in.

One chart is provided for each day, but the observations plotted on it are not all synchronous. The ships' observations are for 1200 G.M.T. ±1 hour. Over the greater part of Europe, North America and North Africa the time of observation is 1300 G.M.T. Over India and Burma the time is 1130 G.M.T., and over the U.S.S.R. it is 1300 L.M.T. except for eastern Siberia where it is 1900 L.M.T. In some small areas the departures are greater. The charts are kept in special folders holding a month's set each, and a chart of station names and times of observation is included in each set.

The complete plotting scheme with key to all symbols is printed on every chart. The data given for each station include pressure, temperature, relative

humidity, pressure change, present and past weather, cloud types and total cloud amount, with the addition for ships of air-sea temperature difference, course and distance traversed in the past three hours. The plotting scheme is that adopted by the International Meteorological Organization Conference of 1935, but it differs little from the one now used and will for the most part be understood without reference to the explanation.

The data for the charts were specially sent by the various national services to the Deutsche Seewarte, and so were much more comprehensive than those received by radio on the day of observation and plotted on current charts. The sea areas, including the Indian Ocean and the tropical Atlantic Ocean, are well covered with ships' observations. There are ten stations north of 75°N. The blank areas are Tibet and Mongolia, central Arabia, a large part of the Sahara, and the Pacific Ocean south-west of California.

Isobars are drawn for every 10 mb. but no other analysis has been placed on the charts. It is noticeable, however, that the isobars are drawn with "frontal" bends.

The charts are more legible and attractive to study than many published charts for very wide areas. The stations have been happily chosen to combine good representation of the weather with legibility and absence of risk of confusion between adjacent stations. The symbols are neatly plotted and are easily read without the aid of a magnifying lens.

The charts should be borrowed from the Meteorological Office Library in sets of months. Also available for lending from the Library are the detailed reports of the observations made at the Polar-Year stations of the various nations. Further, special upper air soundings by aircraft, *ballon-sonde* and pilot-balloon were made by most countries during the Polar Year so that the amount of upper air data available for study in conjunction with the northern-hemisphere charts is greater than for other periods before the introduction of radio-sondes into widespread use.

NOTES ON DE-ICING TRIALS

By R. BOJDYS

In view of the interest aroused by the Meteorological Office Discussion[1] held on October 9, 1950, covering American research into aircraft-icing problems, the following brief note has been prepared regarding some recent British work on the same subject.

During January and February 1950 a series of flight de-icing trials were carried out by the Project Development Branch of British European Airways, using a specially equipped Viking. The flight trials were conducted over a number of areas, including Scandinavia, Germany, the North Sea and the Massif Central in south France.

During the course of the work, some excellent photographs of ice accretion on the aircraft were obtained, these being of special interest in view of the almost complete lack of such pictures taken whilst actually in flight. Some of these are reproduced between pp. 138 and 139. The irregularity of the distribution of the ice shown by the photographs is due to the fact that de-icing fluid was supplied only to certain test sections as part of the investigation. The following details of the five illustrations are given by way of explanation.

Test results, February 27 and 28, 1950.—The flights took place over the North Sea, Trondhjem and Arctic Circle areas at heights of 4,700–8,000 ft. during the period 0930–1230, whilst a ridge of high pressure over Finland was moving slowly westwards. Slight sleet and snow were reported at some coastal stations of northern Norway. The cloud structure consisted of a layer of strato-cumulus, base 1,500–2,500 ft. and tops 4,500–6,500 ft., with variable nimbo-stratus and altostratus clouds between 7,000 and 9,000 ft. No cumulus clouds were observed during these flights. The ice had the appearance of being of the hard-glaze type. A remarkable accretion of ice on the engine intake will be noted from Figs. 4 and 5. This piece of ice finally broke away when the aircraft descended into warmer air, damaging the de-icing distributor on the starboard side. The reduction in airspeed due to the heavy ice accretion was calculated to have been 47 kt. The recorded aircraft temperatures were between −8° and −11·5°C.

I am indebted to the Project Development Department of British European Airways and to Capt. D. Mason, B.E.A., for permission to submit this note. Full details of this work can be found in a report by the Project Development Department of British European Airways.

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2. London, British European Airways, Project Development Department. Vickers Viking fluid de-icing trials 1950. London, 1950.

METEOROLOGICAL RESEARCH COMMITTEE

The 10th meeting of the Instruments Sub-Committee was held on January 25, 1951. The Chairman (Prof. Sheppard) presented a verbal report of encouraging progress which is being made at the Radar Research and Development Establishment on the work of developing a searchlight suitable for investigating the density of the upper air (by measuring the intensity of back scattered light). The Sub-Committee also considered the possibility of using a radar technique for measuring the vertical velocity in cumulonimbus cloud. Recommendations for research on instrumental problems during the next twelve months were agreed.

The Physical Sub-Committee held its 14th meeting on February 8. Some time was spent in considering possible ways of tackling the problem of forecasting the formation and development of radiation fog. The technical papers considered included one by Mr. R. F. Jones[1] on the relation between the radar echoes from convective cloud and the degree of turbulence in the cloud. Recommendations for research on physical problems in meteorology during the next twelve months were agreed.

The main Meteorological Research Committee met for the 61st time on March 15. After hearing annual reports from the Chairmen of Sub-Committees, the Constitution of Sub-Committees and the Research Programme for the next twelve months were approved.

[1] *Met. Res. Pap., London*, No. 593, 1951.

ROYAL METEOROLOGICAL SOCIETY

Recent work on the stratosphere

At the meeting of the Society on February 21, with Dr. R. C. Sutcliffe, a Vice-President, in the Chair, a discussion was held on recent work on the stratosphere.

Sir Charles Normand opened the discussion with some notes on the observation of ozone. It was known that the centre of gravity of ozone was at about 22 Km. (72,000 ft.) and most of the day-to-day variation occurred between 5 Km. (16,500 ft.) and 25 Km. (82,000 ft.). He thought it might be possible to use the quantity of ozone (as measured at the ground by a spectrometer) as a tracer element in the study of the motion of the lower layers of the stratosphere. He showed some up-to-date diagrams of the variation of ozone content compared with the pressure at the tropopause, the temperature at 150 mb. and the reverse of the thickness height, 500–300 mb. They all showed good agreement; but there was occasional disagreement, including an obvious reversal on January 8, 1951, when an occlusion crossed England. He also showed a map of the proposed distribution of ozone spectrometers in western Europe, including four or five in the British Isles (three already in use at Oxford, Downham Market and Camborne) and others in places as far apart as the Azores and Spitsbergen.

Dr. R. Frith, who spoke next, described some humidity measurements made by the Meteorological Research Flight at levels up to 40,000 ft., and, therefore, sometimes not quite in the stratosphere and never very far in. He illustrated an example of a sharp fall of frost point some 2,000 ft. below the tropopause; although the sharp fall usually occurred at the tropopause this sharp fall at a lower level was quite likely in anticyclonic situations. Except for this peculiarity the lapse rate of frost point was approximately the same as that of temperature below the tropopause but considerably greater above, becoming steady at −110°F.

Mr. J. S. Sawyer, the next speaker, considered the synoptic meteorology of the tropopause by inspection of pressure surfaces. In an investigation in the Meteorological Office estimates had been made of the horizontal motion at tropopause level. Potential temperature was conserved at the tropopause and vertical displacements of 1,000 ft./6 hr. had been observed. Thus temperature in the stratosphere was greatly controlled by vertical motion, and air could be observed passing right through a " warm " region. Near jet streams there were sudden discontinuities in the tropopause (a vertical wind shear of 10 kt./1,000 ft. would mean a horizontal change of temperature of about 10°F./100 miles). Mr. Sawyer showed a topographical map of the tropopause with such a tropopause discontinuity round a small area which he called a tropopause " funnel."

Dr. F. J. Scrase then gave an account of further observations made by high-altitude radio-sonde ascents.* The new observations were made at Downham Market and Lerwick, and, to avoid errors due to solar radiation, at 2200 G.M.T. Mean curves showed in winter an increase of temperature with latitude at low stratospheric levels but a decrease at 100,000 ft.; in summer the mean temperature was almost isothermal at low levels in the stratosphere, but increasing again

*The first observations were reported in this magazine: SCRASE, F. J.; Measurement of wind and temperature up to 100,000 ft. by radio-sonde and radar. *Met. Mag., London*, **78**, 1949, p. 284.

at higher levels up to 100,000 ft. In winter winds were westerly at all levels in the stratosphere, but above 60,000 ft. in summer the wind was easterly; the change-over occurred quite sharply at the vernal equinox but more gradually in the autumn; the maximum easterly velocity occurred very near the summer solstice at higher levels. Comparison of temperatures at 100,000 ft. with those made by other methods at varying latitudes from the Panama Canal Zone to Alaska showed a maximum temperature at about 40°N. in both summer and winter. Day-time temperatures showed differences up to 37°F. although it was fairly certain that at least 80 per cent. of this difference was due to radiation errors.

Dr. G. M. B. Dobson summed up by calling attention to the reasons for the increase in knowledge of the stratosphere: the increase in use of radio-sondes, high-altitude aircraft, higher balloon ascents and now rockets; the information obtained from acoustic experiments and ozone measurements; and, finally, because a lot more people were thinking of the stratosphere. He thought the following problems were most important for the near future:—

(i) General circulation of the atmosphere at least up to 30 Km. (100,000 ft.).
(ii) General radiative equilibrium of the stratosphere.
(iii) Physical meaning of the tropopause.
(iv) Ozone observations, particularly the horizontal and vertical distributions.
(v) Humidity, which can be used as a tracer element more satisfactorily than either tropopause temperature or ozone content.

Dr. Dobson said that an instrument for measuring the vertical distribution of ozone from ground observations was available; it gave readings of the ratio of the intensities of radiation on two wave-lengths in the zenith radiation, and these ratios at sunrise and sunset could be plotted against time on very smooth curves (he showed examples). It was possible to use the spectrometer at night with moonlight or even starlight. A general theory relating these observations to the vertical distribution of ozone was still, however, required.

In the general discussion, Mr. E. Gold agreed with Dr. Dobson that there ought to be a better definition of the tropopause to separate out the different kinds from the general average. Dr. Sutcliffe thought the original definition not too bad, there being only five per cent. of rogues. Miss N. Carruthers thought the tropopause " funnel " mentioned by Mr. Sawyer might be part of a frontal surface; Mr. Sawyer was inclined to agree.

Dr. A. W. Brewer drew attention to the measurements of a steady frost point of −110°F. at high levels by the Meteorological Research Flight, and stated that at that temperature the amount of crystallization in the frost-point hygrometer was so small that the instrument was unreliable.

Prof. P. A. Sheppard was interested in the distribution of ozone with latitude, and was told that the observations at Spitsbergen and Tromsø had shown higher distribution in summer at the poles but lower in winter (although records were only available to mid January as yet); there seemed to be a maximum ozone content at 60°N. in winter.

Atmospheric disturbances in the general atmospheric circulation

At the meeting of the Society held on March 21, 1951, with Dr. R. C. Sutcliffe, a Vice-President, in the Chair, Professor E. Palmén of the University of

Helsinki delivered the Symons Memorial Lecture on the role of atmospheric disturbances in the general atmospheric circulation.

Professor Palmén devoted his lecture very largely to the transfer of angular momentum in the general circulation and in temperate-zone depressions.

He pointed out that the formula for the rate of transfer northwards of angular momentum across a parallel of latitude, integrated over the whole depth of the atmosphere, contained one term proportional to the product of the zonal and meridional velocities (transfer of "u-momentum") independent of the earth's angular velocity, and a second term proportional to the earth's angular velocity and to the mean of the meridional velocity over the whole depth of the atmosphere (transport of "ω-momentum").

Over a long period of time the second term vanishes as there is no net meridional transfer of air. Now the area in which angular momentum is transferred from the earth to the atmosphere is the equatorial zone, and the area in which the angular momentum is transferred back to the earth is in the zone of the temperate westerlies. Over a long time, therefore, the maximum rate of northward transfer of angular momentum should be found in the area occupied by the subtropical anticyclones where, however, the surface winds are very light. Professor Palmén showed meridional sections for both the northern and southern hemispheres from which it was clear that there was a maximum of the upper westerlies at about the tropopause level over the surface subtropical anticyclones. Angular momentum thus had to be transferred up to the tropopause level and then carried away northwards. Professor Palmén went on to point out that, though the picture seemed qualitatively clear, considerable difficulty was found when quantitative calculation of the meridional flow was attempted. The angular momentum generated in the equatorial zone was ω-momentum associated with the earth's angular velocity and this had to be converted into u-momentum. This transformation of ω-momentum to u-momentum goes on principally, he considers, at about the 200-mb. level. A vertical circulation was essential to produce a wind distribution such that large-scale eddies can transport the angular momentum polewards.

In the second part of his lecture Professor Palmén considered angular-momentum transport as a factor in temperate-zone depressions. He gave a figure showing that angular momentum was transported northwards in the west and east parts of a depression and southwards in the centre. This transport and associated transformation of momentum into geostrophic wind tended to tilt troughs of low pressure into a south-west to north-east direction.

Professor Palmén next considered the application of angular-momentum theory to the subsidence of the cold air of depressions. The rate of transport of momentum at a specified pressure level is proportional to the difference between the rate of change of the area occupied by the cold air and the rate of change which would be expected at the same level as a consequence of advection alone. This difference in turn depends on the vertical velocity. He gave an interesting table of the subsidence calculated in this way for levels from 900 mb. to 400 mb. behind a cold front.

Finally, he gave a diagram showing his tentative conception of momentum transport along a meridian which shows the main circuit as upward in the equatorial zone, northward from lat. 25° and downwards in the cold air of the depressions of the temperate zone.

LETTER TO THE EDITOR

Simultaneous occurrence of aurora and luminous night clouds

A display of luminous night (noctilucent) clouds, even more extensive and striking than that of July 10–11, 1949[1] was visible above the northern horizon in central Scotland during the night of July 24–25, 1950. Photographs of the clouds taken at Abernethy, Perthshire, are reproduced between pp. 138 and 139.

About 2200 G.M.T., there appeared simultaneously a diffuse auroral arc (with base at an elevation of 10° and sunlit rays) and beneath it luminous night clouds reaching an elevation of 5° (Fig. 1). The appearance together of these two phenomena is surely an extremely rare occurrence.

As twilight waned, the auroral luminescence either ceased or was extinguished by the steadily increasing brilliance of the clouds, which by 0050 G.M.T. had extended to an altitude of nearly 25° and stretched along the horizon between azimuths of 345° and 85° (Fig. 2). Their luminosity was sufficiently great to allow notes to be written without the aid of artificial light.

By contrast with the display of July 10–11, 1949, when the cloud mass remained blue in colour throughout, portions of the cloud in this display were observed to change colour from vivid blue to white, a transformation that suggests growth of the particles.[2] Spectrographic analysis of the light from the clouds during the development of a brilliant display of this kind would be likely to yield valuable information concerning the nature of the cloud particles.

As Professor Størmer had recommended that examination of the clouds by radar should be attempted, search was made during the night from Lerwick Observatory, but no response was obtained. Though the clouds depicted in Fig. 2 were situated over Shetland, overcast skies prevented visual observations at Lerwick.

J. PATON

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1. PATON, J.; Luminous night clouds. *Met. Mag., London*, **78**, 1949, p. 354.
2. PATON, J.; Luminous night clouds. *Met. Mag., London*, **79**, 1950, p. 87.

REVIEW

Methods in climatology. By V. Conrad and L. W. Pollak. 9½ in. × 6¼ in., pp. xxiv + 459, *Illus.*, Harvard University Press (London: Geoffrey Cumberlege) 2nd edn., 1950. Price : $7.50 or 48*s.* 0*d.*

In "Handbuch der Klimatologie" edited by Köppen and Geiger, Dr. Conrad contributed the general section on climatic elements.* The methodological parts of this probably formed the nucleus of the first edition of the book now under review. The latter is a handbook designed for the geographer or climatologist. It encourages in him a critical survey of numerical data and reminds him of the items to be included in descriptions of climate as well as providing him with simple tools for new lines of investigation.

*KÖPPEN, W. and GEIGER, R.; Handbuch der Klimatologie. Band I. Teil B: Der klimatologischen Elemente und ihre Abhangigkeit von terrestrischen Einflüssen. By V. Conrad, Berlin, 1936.

In the second edition, Dr. Conrad has collaborated with Dr. Pollak, known best perhaps for his papers on periodogram analysis; revisions and additions have been made to the original text, now comprising Part I, and a new Part II has been added, dealing with computing machines and periodicity.

Part I retains, in the main, its simplicity and explicitness, its stressing of small points all too often overlooked; mathematical details are simple, seldom requiring more knowledge than the recognition of a summation symbol; but, in the first five chapters, the reader is greatly harassed by numerous forward references to later chapters. After introductory remarks on climatic elements and the organization of a network of observing stations, there follow chapters on elementary statistics, curve fitting and harmonic analysis. A new chapter, " Aids to computation ", is obscure in parts; but it gives a clear account of simple nomograms and includes a useful list of published tables. In Chapters 6 and 7, climatic elements receive individual study; Chapter 8 deals with comparisons between two or more series of observations and includes correlation; Chapter 9 is concerned mainly with mapping; while Chapter 10 gives notes and hints on the preparation of climatic monographs. Of interest in Chapter 7 is the fitting of frequencies of daily rainfall amounts by a modified form of the Poisson series. The more familiar, binomial and (simple) Poisson series, however, are nowhere mentioned; and neither sequences nor " persistence " of discrete phenomena are discussed.

In Part II, a welcome addition to the volume is the chapter on punched cards and other computing devices; it is easy to read and full of interesting facts. The addition of the three chapters on periodicity however, overburdened as they are with mathematical formulæ, would seem to have increased the cost more than the usefulness of the volume. Brief abstracts of these chapters, supplemented by references, would be more in keeping with the elementary treatment characteristic of Part I, although Fig. 107, illustrating the resolving power of the Schuster spectrum, and the calculation of correlograms from harmonic components are worth including. Discussion of the reality of periodicities in Chapter 13 might well be replaced by a simple, clearly described table of significant amplitudes. The same comment applies to the discussion of the reality of correlation coefficients in Chapter 8*. The authors are not pledged to write a text-book of statistics and so need include only those applications of statistical theory which are necessary for a general, but fairly simple, guide to methods in climatology.

The book is neatly bound, and its smooth pages, clear print and diagrams and ample references to literature make it at once pleasing and useful. It would, however, have been greatly enhanced by more careful revision and editing. Numerous footnotes, duplication of symbols, and references by section numbers, sometimes misprinted, are tiresome things which make for disjointed reading; and, surely, so elegant a publication was worthy of a new line block to eliminate the errors of Fig. 71! There is much to praise, much to criticize; but, happily, the faults are minor ones. The reviewer finds no gravely misleading statements in this second edition, and recommends it, without hesitation, both for lively interest and for reference.

N. CARRUTHERS

*Compare Table VI of FISHER R. A. and YATES, F.; Statistical tables for biological, agricultural and medical research. 2nd edn, London and Edinburgh, 1943.

OBITUARIES

Prof. Dr. Reinhard Süring.—We regret to report the death on December 29, 1950, of Prof. Süring. He was aged 85.

Prof. Süring was well known to British meteorologists as a pioneer in the investigation of the upper air, as part-author of the later editions of the "Lehrbuch der Meteorologie", and as part-editor of the *Meteorologische Zeitschrift* and of the "International cloud atlas".

He joined the staff of the Prussian Meteorological Institute in 1890. After working in the Thunderstorm and Instruments Sections at the Central Institute he was appointed Head of the Meteorological Section of the Potsdam Observatory in 1909, and succeeded the magnetician A. Schmidt as Director of the Observatory in 1928. He retired in 1932 on reaching the age limit. He returned to the Observatory in 1945 as Leader of the Meteorological Service of the Soviet Occupation Zone until retiring again in April 1950.

About the turn of the century Süring played a prominent part in the investigations of the upper air by means of manned free-balloon flights conducted by the Deutscher Verein zur Forderung der Luftschiffahrt. He took part in many of the ascents, establishing with Berson a height record for a manned balloon of 10,890m., and worked with Assmann, Berson and others in the study of the observations. The chapters on water vapour and on cloud forms in the monumental publication describing the results of these flights, "Wissenschaftliche Luftfahrten", were written by him.

In 1908 Süring became part-editor of the *Meteorologische Zeitschrift*, serving successively with Hann, Exner and Steinhauser until that famous periodical ceased publication in 1944. In 1946 he organized the publication of the *Zeitschrift für Meteorologie* of which he was editor until the year of his death.

Hann made him, in 1915, his collaborator in writing the third edition of his "Lehrbuch der Meteorologie", thereafter known universally as "Hann-Süring". Publication of the fifth edition of the Lehrbuch began under Süring's editorship in 1939 and after much delay owing to the war is now nearly completed.

Smaller works from Süring's pen are his "Leitfaden der Meteorologie", effectively the Lehrbuch abbreviated, and "Die Wolken" written to supplement the "International cloud atlas" by describing the physics of clouds.

Mrs. E. V. Newnham, M.Sc.—I learned with great regret of the death of Mrs. E. V. Newnham on Sunday, March 11, after a long and painful illness. May I pay a tribute to her memory and express on behalf of her friends in, or retired from, the Meteorological Office their sympathy with her husband and family in their great loss.

Mrs. Newnham, then Miss Gertrude Cocks, entered the Office as a Professional Assistant in the Forecast Branch at South Kensington towards the end of the first world war. She soon showed her ability and Sir Napier Shaw invited her to prepare a memoir on tropical hurricanes about which there was then no comprehensive published account. She undertook the task, no light one as is

evident from the following extract from Sir Napier Shaw's preface: " Considering the enormous amount and complexity of the material which is available in various forms and the mixture of theory and fact which can hardly be disentangled in the original papers, the presentation of the salient features of the history of the tropical revolving storms of the globe is not by any means an easy matter."

Meantime she married, but, fortunately, as she was prepared to carry on, a sensible dispensation abrogated in her case the rule about retirement on marriage. She completed the work and produced one of the best memoirs of a memorable series. *Geophysical Memoirs*, No. 19, " Hurricanes and tropical revolving storms " is a standard work of reference and this contribution to meteorological knowledge stands as a permanent memorial of a gifted woman.

E. GOLD

Mr. R. T. Cornish.—It was with great regret that we learned of the death on March 20 of Mr. R. T. Cornish who served as a forecaster in the Meteorological Office from 1941 to 1946.

After he had been with us for eighteen months Mr. Cornish was chosen for a difficult task demanding a high degree of discretion and discernment; by his tact and diplomacy Mr. Cornish fully justified his selection for the post.

Though Mr. Cornish returned to an academic life at the end of the war he did not sever his connexion with the Office. Meteorology was included in the courses he gave as a lecturer in geography at University College, London, and he was a frequent visitor to the Office Library at Harrow where he was always welcome.

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—The part played by o.w.s. *Weather Explorer*, on duty at station JIG, in the search for the missing Globemaster aircraft, U.S.A.F.C-124, during the period March 24–30, 1951, was recognized by the United States Air Force Authorities by a personal signal of appreciation from Major General Anderson.

The Netherlands o.w.s. *Cumulus* relieved the *Weather Explorer* at station JIG on April 7.

Overseas students at the Meteorological Office Training School.—During the past few years a number of overseas meteorological services have asked for forecasting courses to be provided for selected members of their staff at the Meteorological Office Training School. These requests have been complied with whenever possible, the normal practice being to reserve the required number of vacancies on courses which have already been planned for Office staff.

Since the end of the war there have been few forecasting courses which have not included at least one student from abroad. Within the Commonwealth, Ceylon, Nigeria, and Hongkong have sent locally recruited staff to England for training, and students have also come from Europe (Belgium and Greece), the Middle East (Iraq and Persia), Asia (Siam) and South America (Peru).

Language difficulties have not been serious, a fact which bears witness to the widespread knowledge and use of the English language rather than to the linguistic abilities of the instructors.

After their forecasting course at the school the visitors usually spend a few weeks visiting Dunstable and such offices as those at London Airport and Northolt where operational procedures are studied at first hand. Some of the students go to Downham Market to learn about the operation of radio-sonde and radar-wind equipment and students from Ceylon have also visited Eskdalemuir Observatory for instruction in terrestrial magnetism.

Loan of instruments for exploring expeditions.—The exploration societies of the various universities and schools, now planning expeditions to be made during the long vacation, have once more asked the Office to lend instruments for their meteorological work.

Applications for the loan of instruments have been received from the Durham University Exploration Society for an expedition to Breida Merku Jökull (Vatna Jökull) Iceland, from Birmingham University for an expedition to west Spitsbergen, and from the British Schools' Exploring Society for an expedition to central Iceland around the Hofs Jökull Glacier. The main interests of the first two expeditions are geology and glaciology, though meteorology is a necessary handmaiden to these subjects.

The Durham University Exploration Society hopes, with the permission of the Icelandic Government, to set up a permanent climatological station in Iceland.

The meteorological officer to the British Schools' Expedition will be Mr. R. H. A. Stewart who served in the Meteorological Section, R.A.F.V.R., from 1944 to 1947 and afterwards as a civilian in the Office until he took up an appointment as an instructor at Pangbourne Nautical College in 1949.

Climatological stations.—The climatological station at Southend-on-Sea has been maintained for many years by the Pier and Foreshore Department of the local council. When, in February 1951, the Council decided to discontinue full operation of the station, Mr. E. J. Cotgrove and Mr. A. Clothier undertook to take the readings on Sundays so that records would be available for inclusion in the *Monthly Weather Report*. We should like to join with the Council in expressing appreciation to these two gentlemen for their public-spirited action.

Overseas tours.— It will be welcome news to the staff to learn that the length of tour in Mauripur and in Asmara has been reduced to 2½ years.

Mr. R. S. Read, who retired from the Office on December 4, 1950, has been appointed Assistant Librarian of the Royal Meteorological Society.

Retirement of Dr. R. E. Watson.—The Office has lost the services of another of its senior officers in the person of R. E. Watson, Ph.D., who retired on March 31, 1951. Dr. Watson joined the Office in March 1918, having been twice wounded in the 1914–18 war and invalided out of the Army. The first fourteen years of his service were spent on the staff of the Observatories at Falmouth, Kew and Eskdalemuir. He was at Kew Observatory for nine years, first under Dr. Charles Chree and then under Dr. F. J. W. Whipple, and was later Superintendent at Eskdalemuir. This period of Observatory work was

most fruitful scientifically: he wrote several papers on radiation and atmospheric electricity, and collaborated with Dr. Chree in two papers on atmospheric pollution and terrestrial magnetism.

From 1934 onwards Dr. Watson was concerned with meteorological services for the Royal Air Force. In the early war years he surveyed war-time requirements of the meteorological training of aircrew. Later he was Senior Meteorological Officer at a group headquarters in Bomber Command with control of a number of subsidiary meteorological offices and took an active part in forecasting for bomber operations. He occupied other highly responsible meteorological posts in Royal Air Force Commands both during and after the war.

At an informal gathering on April 2 the Principal Deputy Director, Dr. Stagg, conveyed the good wishes of the staff to Dr. Watson and asked him to accept a silver cigarette box for which the staff had subscribed. Dr. Stagg referred to Dr. Watson's long association with, and good work for, the Office and made good humoured reference to his qualities of sportsmanship and *bonhomie*. In his reply, Dr. Watson paid tribute to those high-ranking officers in the Royal Air Force with whom he had worked closely and from whom he had received so much willing co-operation, help and appreciation, and to the loyalty and hard work of the meteorological officers who served with him.

WEATHER OF MARCH 1951

Mean pressure of over 1020 mb. extended from Canada to Greenland, while it was above 1030 mb. over parts of north Canada. It was between 1020 and 1010 mb. over North America and also in the area extending from north-west Africa, the west Mediterranean and Spain westwards into the Atlantic. Mean pressure below 1010 mb. occurred over the British Isles and north Europe and also over Italy.

Mean pressure was about 10 mb. above normal in the north-west Atlantic south of Greenland, and about 5 mb. below normal over the British Isles and north Europe.

In the British Isles the weather was unsettled, with depressions constantly passing over or near the country, particularly across England and Wales. It was cold, with frequent showers of sleet or snow, and rainfall was unusually heavy in England and Wales, but less than the average occurred over much of central and western Scotland.

During the first four days of the month a belt of high pressure extended across the British Isles. Weak fronts, however, caused slight rain on the 1st and 2nd, and, on the 4th, a trough over our north-west coasts was associated with some rain in Scotland and Ireland. Widespread fog occurred on the 1st and 2nd. On the 6th and 7th a depression west of Scotland moved south, while a secondary which developed south-westward of Ireland moved east to the western English Channel, and subsequently swung north, then west and finally south-west. Heavy precipitation occurred in the south-west on the 6th, and more was recorded in western districts on the 7th, while thunder was experienced locally in Ireland. By the 9th pressure was high off the south of Greenland; meanwhile a shallow depression over France moved north and another off south-west Norway moved south-south-west and then west-south-west across the north of Scotland. Cold north-easterly winds prevailed on the 9th, becoming rather

variable on the 10th; widespread sleet or snow occurred, being heavy in the north of Scotland on the 10th. Thereafter a depression over south-west France moved north-east causing further precipitation (around the 10th–12th snow lay to a depth of 6–12 in. at Dalwhinnie and Glenlivet and at 0900 on the 13th level snow lay 7 in. deep at Bwlchgwyn in north Wales). On the 13th and 14th a deep depression off north Portugal moved quickly north-east across England to the North Sea and thence east across Denmark. Temperature rose and rain occurred on the 13th and scattered, slight rain on the 14th. In the rear of this depression a ridge of high pressure built up over the British Isles giving a rather warm, sunny day on the 15th. From the 16th to the 18th a depression was situated westward of Ireland, while associated secondary depressions moved north-east across England. Temperature continued fairly high in southern districts, while rain fell in most areas and was rather heavy at times in England and Wales. On the 19th the main depression, now situated over south-west Ireland, moved east-south-east, and on the 19th and 20th an anticyclone to the north-west of Scotland moved south-east across the British Isles to the Low Countries; scattered showers, wintry in places, occurred on the 19th and a fair, sunny day (except in the extreme south-west and west) on the 20th. A return to more unsettled conditions ensued on the 21st, when an Atlantic depression moved quickly north-east to the north of Scotland and an associated trough crossed the British Isles; heavy rain was widespread on the 21st, and occurred in the west and north also on the 22nd (2·47 in. at Barnacarry, on Loch Fyne, Argyll, on the 21st, 4·25 in. at Loch Sloy Dam, Dumbartonshire and 3·01 in. at Glen Etive, Argyll on the 22nd). Temperature rose to between 55°F. and 60°F. at a number of stations on the 22nd and in most areas this was the warmest day of the month. The depression moved away east, and by the 23rd was situated over south Sweden, and, in its rear, a cold north-westerly air stream covered the British Isles causing a considerable fall in temperature. From the 24th to the 26th a depression south of Iceland moved east-south-east over the British Isles, later turning east across the North Sea; rather cold weather prevailed, with wintry showers and long bright periods on the 25th and 27th, but more general rain or snow on the 26th. Again, from the 28th to the 30th, another disturbance moved south-south-east from the south of Iceland; rain and snow occurred and the weather continued cold but with long, sunny periods. On the closing day of the month a trough of low pressure moved east across the country causing precipitation, mostly in the form of rain, but sleet or snow in places and local thunderstorms in England and Wales.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	60	19	−2·0	175	+4	83
Scotland	57	3	−2·7	95	+1	82
Northern Ireland ...	57	17	−2·0	97	0	87

RAINFALL OF MARCH 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.
London	Camden Square ...	3·22	176	*Glam.*	Cardiff, Penylan ...	4·11
Kent	Folkestone, Cherry Gdn.	3·31	153	*Pemb.*	Tenby, The Priory ...	4·79
,,	Edenbridge, Falconhurst	3·97	160	*Card.*	Aberystwyth	4·23
Sussex	Compton, Compton Ho.	5·92	214	*Radnor*	Tyrmynydd	6·92
,,	Worthing, Beach Ho. Pk.	3·44	179	*Mont.*	Lake Vyrnwy	6·81
Hants.	Ventnor, Roy. Nat. Hos.	4·75	226	*Mer.*	Blaenau Festiniog ...	12·43
,,	Bournemouth	3·56	153	*Carn.*	Llandudno	5·27
,,	Sherborne St. John ...	4·06	181	*Angl.*	Llanerchymedd ...	4·88
Herts.	Royston, Therfield Rec.	3·18	174	*I. Man*	Douglas, Borough Cem.	4·23
Bucks.	Slough, Upton	3·56	202	*Wigtown*	Port William, Monreith	3·36
Oxford	Oxford, Radcliffe ...	3·55	215	*Dumf.*	Dumfries, Crichton R.I.	2·90
N'hants.	Wellingboro', Swanspool	3·28	183	,,	Eskdalemuir Obsy. ...	5·30
Essex	Shoeburyness	2·13	158	*Roxb.*	Kelso, Floors	2·87
,,	Dovercourt	2·59	168	*Peebles*	Stobo Castle	2·50
Suffolk	Lowestoft Sec. School ...	2·59	161	*Berwick*	Marchmont House ...	3·13
,,	Bury St. Ed., Westley H.	3·86	204	*E. Loth.*	North Berwick Res. ...	2·58
Norfolk	Sandringham Ho. Gdns.	3·95	208	*Midl'n.*	Edinburgh, Blackf'd. H.	2·58
Wilts.	Bishops Cannings ...	3·52	156	*Lanark*	Hamilton W. W., T'nhill	2·25
Dorset	Creech Grange... ...	5·09	180	*Ayr*	Colmonell, Knockdolian	3·28
,,	Beaminster, East St. ...	4·38	149	,,	Glen Afton, Ayr San ...	4·46
Devon	Teignmouth, Den Gdns.	4·57	176	*Bute*	Rothesay, Ardencraig ...	3·72
,,	Cullompton	4·40	161	*Argyll*	Morvern (Drimnin) ...	4·47
,,	Ilfracombe	4·84	168	,,	Poltalloch	4·10
,,	Okehampton, Uplands	5·75	139	,,	Inveraray Castle ...	5·42
Cornwall	Bude, School House ...	4·68	192	,,	Islay, Eallabus	4·07
,,	Penzance, Morrab Gdns.	5·39	168	,,	Tiree	3·01
,,	St. Austell	5·65	164	*Kinross*	Loch Leven Sluice ...	3·52
,,	Scilly, Tresco Abbey ...	4·91	187	*Fife*	Leuchars Airfield ...	2·27
Glos.	Cirencester	3·91	169	*Perth*	Loch Dhu	4·88
Salop	Church Stretton ...	5·20	216	,,	Crieff, Strathearn Hyd.	1·92
,,	Shrewsbury, Monksmore	4·15	249	,,	Pitlochry, Fincastle ...	1·91
Worcs.	Malvern, Free Library	4·62	238	*Angus*	Montrose, Sunnyside ...	2·54
Warwick	Birmingham, Edgbaston	5·14	269	*Aberd.*	Braemar	2·37
Leics.	Thornton Reservoir ...	3·37	183	,,	Dyce, Craibstone ...	2·89
Lincs.	Boston, Skirbeck ...	3·19	205	,,	Fyvie Castle	3·07
,,	Skegness, Marine Gdns.	3·03	183	*Moray*	Gordon Castle	3·02
Notts.	Mansfield, Carr Bank ...	4·28	205	*Nairn*	Nairn, Achareidh ...	1·44
Derby	Buxton, Terrace Slopes	7·85	190	*Inverness*	Loch Ness, Garthbeg ...	2·13
Ches.	Bidston Observatory ...	4·28	225	,,	Glenquoich	5·94
Lancs.	Manchester, Whit. Park	4·57	202	,,	Fort William, Teviot ...	3·74
,,	Stonyhurst College ...	4·51	122	,,	Skye, Duntuilm ...	3·05
,,	Squires Gate	4·44	196	*R. & C.*	Tain, Tarlogie House ...	2·05
Yorks.	Wakefield, Clarence Pk.	2·92	162	,,	Inverbroom, Glackour...	4·03
,,	Hull, Pearson Park ...	2·85	157	,,	Applecross Gardens ...	3·00
,,	Felixkirk, Mt. St. John	2·80	142	,,	Achnashellach	4·88
,,	York Museum	2·69	160	,,	Stornoway Airfield ...	2·44
,,	Scarborough	3·34	186	*Suth.*	Loch More, Achfary ...	6·08
,,	Middlesbrough... ...	3·13	199	*Caith.*	Wick Airfield	3·65
,,	Baldersdale, Hury Res.	3·59	116	*Shetland*	Lerwick Observatory ...	2·46
Norl'd.	Newcastle, Leazes Pk....	3·58	174	*Ferm.*	Crom Castle	3·19
,,	Bellingham, High Green	3·08	105	*Armagh*	Armagh Observatory ...	2·78
,,	Lilburn Tower Gdns. ...	3·74	141	*Down*	Seaforde	3·03
Cumb.	Geltsdale	4·33	155	*Antrim*	Aldergrove Airfield ...	2·09
,,	Keswick, High Hill ...	4·46	99	,,	Ballymena, Harryville...	2·20
,,	Ravenglass, The Grove	4·35	141	*L'derry*	Garvagh, Moneydig ...	2·67
Mon.	Abergavenny, Larchfield	4·55	150	,,	Londonderry, Creggan	3·31
Glam.	Ystalyfera, Wern House	6·45	120	*Tyrone*	Omagh, Edenfel ...	3·33